CLAIMS

1. A light source estimation apparatus to correctly estimate the image-pickup light source, in which from sensor response values obtained upon pickup of an image of an unspecified arbitrary object, image-pickup means having a plurality of different spectral sensitivity characteristics estimates spectral characteristics indicating color of an unknown image-pickup light source irradiating an object, comprising:

storage means for storing, for each test light source, parameters for projecting said sensor response values into an evaluation space not dependent on said image-pickup light source by performing operations which can be colorimetrically approximated from a plurality of different said known spectral sensitivity characteristics of said image-pickup means and from the spectral characteristics of a plurality of test light sources assumed in advance;

projection conversion means for projecting said sensor response values into said evaluation space not dependent on the image-pickup light source using parameters stored in said storage means; and,

evaluation means for evaluating the correctness of said plurality of test light sources based on the image distribution state of sample values of an image scene projected by said projection conversion means.

2. A light source estimation method in which from sensor response values obtained upon pickup of an image of an unspecified arbitrary object, image-pickup means having a plurality of different spectral sensitivity characteristics estimates spectral characteristics indicating color of an unknown image-pickup light source irradiating an object, comprising the steps of:

projecting said sensor response values into an evaluation space not dependent on the image-pickup light source through operations which can be colorimetrically approximated from known spectral sensitivity characteristics of image-pickup means and from spectral characteristics of an assumed test light source; and

estimating the correct image-pickup light source by evaluating the correctness of a plurality of said test light sources based on a state of distribution of sampled values of the projected scene.

3. The light source estimation method according to claim 2,

wherein a vector space for said evaluation is a space in which weighting coefficients used to approximate the spectral reflectivity of diverse object surfaces by conjoining a

plurality of reflectivity basis functions, represent the spectral reflectivity characteristics specific to an object surface, or a space in which the weighting coefficients become further converted values through fixed operations.

4. The light source estimation method according to claim 3,

wherein said reflectivity basis functions to approximate the spectral reflectivity are spectral reflectivity components obtained by statistical analysis of the spectral reflectivity data of a plurality of known object surfaces as a population; are intentionally extracted spectral reflectivity components; or are a combination of both.

5. The light source estimation method according to claim 2,

wherein a vector space for said evaluation is a space in which spectral distribution values for light reflected on an object surface from a single virtual reference light source having a specific spectral distribution are converted into a plurality of channels by fixed operations.

6. The light source estimation method according to claim 5,

wherein a reference light source, said spectral distribution of which is fixed over a wavelength range, is used.

7. The light source estimation method according to claim 2,

wherein a plurality of light sources with different known spectral distributions are taken to be said test light sources; spectral distribution data for each test light source or coefficients for computation corresponding to each test light source to which said spectral distribution data is applied are stored in advance; and the data or coefficients are referenced at the time of said light source estimation.

8. The light source estimation method according to claim 2,

wherein a plurality of different representative light sources are extracted and stored in advance as said test light sources from among spectral distribution data for various known light sources, from among coefficients to approximate the spectral distribution data by weighted linear sums of a plurality of light source basis functions, or from among indexes obtained using fixed computation formula from the spectral distribution data; and the spectral distribution data of each of the test light sources, or the computation coefficients

corresponding to each of the test light sources to which the data is applied, are referenced at the time of said light source estimation.

9. The light source estimation method according to claim 8,

wherein, as the information for the plurality of different light sources stored in advance, spectral distribution data for a specific light source or computation coefficients corresponding to a specific light source to which the distribution data is applied are used; and said plurality of test light sources are generated and referenced by appropriate selection, interpolation processing, or the like at the time of said light source estimation.

10. The light source estimation method according to claim 7,

wherein said plurality of representative test light sources are categorizable by the color temperature value of the light source, by the physical light emission method of the light source, or by both.

11. The light source estimation method according to claim 2,

wherein, among the sensor response values of said image-pickup means, values with respect to all pixels or values with respect to pixels sampled at appropriate positions, in appropriate ranges, and at appropriate intervals within the spatial position of the image-pickup plane are used.

12. The light source estimation method according to claim 2,

wherein, among the sensor response values of said image-pickup means, values with respect to only pixels the values for each channel of which are in a specified range, or values with respect to all pixels other than pixels the values for each channel of which are in a specified range are used.

13. The light source estimation method according to claim 2,

wherein, at the time of projecting sensor response values of said image-pickup means into evaluation space, or prior to said time, scaling is performed at a fixed arbitrary ratio or at an appropriate ratio determined in advance according to image-pickup results.

14. The light source estimation method according to claim 2,

wherein sensor response values of said image-pickup means are used after adding noise, exposure error, or other temporally fluctuating quantities supposed in said image-pickup means, or after adding pixels to which such fluctuating quantities have been added.

15. The light source estimation method according to claim 2,

wherein with respect to each of said test light sources, a statistical quantity obtained from values of sample pixels projected into evaluation space; a statistical quantity obtained from an image distribution indicating the frequency distribution in evaluation space generated from sample pixels; a statistical quantity obtained from the image color gamut indicating the region in the evaluation space in which sample pixels are distributed; or a combination of any two or more of these, are used, either without further modification, or after conversion into values by a fixed operation, as said estimation criterion for an index of correctness assumed in advance.

16. The light source estimation method according to claim 2,

wherein a statistical quantity obtained from sample pixels in sensor space of said sensor response values, or a statistical

quantity obtained from values converted by a fixed operation from sample pixel values in sensor space, are projected into evaluation space with respect to each of said test light sources, and are used, either without further modification, or after conversion into values by a fixed operation, as said estimation criterion for an index of correctness assumed in advance.

17. The light source estimation method according to claim 15,

wherein, with respect to the spectral reflectivity of an object surface, an index of the correctness of each of said test light sources is calculated in advance using statistical quantities added constraints or weighting formable in a specific region of the evaluation space, based on the physical possibility in the range from 0 to 1 at each wavelength and on an assumed probabilistic distribution in the real world in which, on average, there exist numerous surface approximating achromaticity with a flat wavelength characteristic.

18. The light source estimation method according to claim 2,

wherein, with respect to each of said test light sources, a correlation function of a reference color gamut recorded in advance, referenceable, and indicating the range of appearance

in the evaluation space; with sample pixel values projected into the evaluation space; with the frequency distribution in the evaluation space generated from the sample pixels; with the region in the evaluation space in which sample pixels are distributed; or with a combination of any two or more of same, is used as an index of said estimation criterion.

19. The light source estimation method according to claim 18,

wherein a weighting distribution and region information generated from the frequency distribution in the evaluation space of values converted from spectral reflectivity data of various object surfaces into coefficients approximated by reflectivity basis functions, or of values obtained by converting said coefficients by a fixed operation, are used as said reference color gamut.

20. The light source estimation method according to claim 18,

wherein a weighting distribution and region information generated from the frequency distribution of values, in which sensor response values which are either the result of image pickup of a variety of actually existing scenes or the result of predicting by numerical operations the images picked up for a

variety of virtual scenes are projected into evaluation space for each scene using operations capable of colorimetrically approximating from spectral sensitivity characteristics of said image-pickup means and from spectral distribution characteristics of the image-pickup light source measured at the time of image pickup of each scene, are used as said reference color gamut.

21. The light source estimation method according to claim 18,

wherein, with respect to spectral reflectivity of an object surface, a weighting distribution and region information generated from a frequency distribution determined based on a physical possibility in the range 0 to 1 at each wavelength and on an assumed probabilistic distribution in the real world in which, on average, there exist numerous surface approximating achromaticity with a flat wavelength characteristic, are used as said reference color gamut.

22. The light source estimation method according to claim 19,

wherein, before or after generating said reference color gamut from any of said frequency distributions or from a combination thereof, with respect to the distribution in

evaluation space, interpolation, extrapolation, removal, spatial filtering, or other processing according to fixed criteria are performed.

23. The light source estimation method according to claim 15,

wherein, in generation of an index of correctness for each of said test light sources, in order to emphasize the high color saturation region in which the difference between test light sources appears more prominently in the evaluation space, the image distribution is extracted and weighted operations are performed on the outline or in the vicinity thereof in the image color gamut.

24. The light source estimation method according to claim 15,

wherein, with respect to the image distribution or image region of sample pixels projected into the evaluation space, after performing interpolation, extrapolation, removal, spatial filtering, or other processing according to fixed criteria, an index of correctness is calculated for each of said test light sources.

25. The light source estimation method according to claim 15,

wherein a plurality of different indexes generated from sample pixel values projected into a single evaluation space, or a plurality of different indexes generated from sample pixel values projected into a plurality of different evaluation spaces, are conjoined by numeric means; are selected by conditional branching; or are both combined, to generate a new index used to evaluate the correctness of each of said test light sources.

26. The light source estimation method according to claim 2,

wherein the test light source having the highest index of correctness among said plurality of test light sources is determined as the estimated light source.

27. The light source estimation method according to claim 2,

wherein the weighted averages of two or more light sources having high correctness among said plurality of test light sources is determined as the estimated light source.

28. The light source estimation method according to claim 26,

wherein a process, in which the light source with the highest index of correctness among said plurality of test light sources is initially selected, and different light sources obtained in finely divided vicinity of said selected light source are referenced to generate indexes of correctness for each light source, is repeated.

29. The light source estimation method according to claim 26,

wherein said test light sources include two or more categories according to physical light emission method; color temperature judgment processing based on an index indicating that, within each category, the color temperature is closest to the color temperature of the image-pickup light source, and light emission method judgment processing based on an index indicating that the light source is closest to the physical light emission method of the image-pickup light source, using the same or another index, are performed; and the estimated light source is determined from both the judgment results.

30. The light source estimation method according to claim 26,

wherein said test light sources include two or more categories according to physical light emission method, and the

estimated light source is determined based on an index indicating a light source closest to the image-pickup light source, with respect only to a test light sources belonging to a category specified by the user or to a category provided by category judgment means differing from said estimation means.

31. The light source estimation method according to claim 2,

wherein the image-pickup light source determined by said estimation and a light source determined by an estimation method different from said estimation are conjoined by numeric means, are selected by conditional branching, or are both combined, to determine the final estimated light source.

32. An image-pickup apparatus in which from sensor response values obtained upon pickup of an image of an unspecified arbitrary object, image-pickup means having a plurality of different spectral sensitivity characteristics estimates spectral characteristics indicating color of an unknown image-pickup light source irradiating an object, and which uses, in color balance processing of the sensor response of said image-pickup means, the spectral characteristics which are the color of the estimated light source or parameters appropriate thereto, comprising:

storage means for storing, for each test light source, parameters for projecting said sensor response values into an evaluation space not dependent on said image-pickup light source by performing operations which can be colorimetrically approximated from a plurality of different said known spectral sensitivity characteristics of said image-pickup means and from the spectral characteristics of a plurality of test light sources assumed in advance;

projection conversion means for projecting said sensor response values into said evaluation space not dependent on the image-pickup light source using parameters stored in said storage means;

evaluation means for evaluating the correctness of said plurality of test light sources based on the image distribution state of sample values of an image scene projected by said projection conversion means;

light source estimation means for estimating the final image-pickup light source to be determined as the estimated light source by conjoining in numerical formulas, by selecting through conditional branching, or by combining both of, an image-pickup light source determined by said estimation and a light source determined by an estimation method different from said estimation; and

color balance adjustment means which uses spectral characteristics, which are the color of the estimated image-

pickup light source, or parameters appropriate thereto in color balance processing of the sensor response of said image-pickup means.

33. An image processing method in which from sensor response values obtained upon pickup of an image of an unspecified arbitrary object, image-pickup means having a plurality of different spectral sensitivity characteristics estimates spectral characteristics indicating color of an unknown image-pickup light source irradiating an object; and which uses the spectral characteristics, which are the color of the estimated light source, or parameters appropriate thereto in color balance processing of the sensor response of said image-pickup means, comprising the steps of:

projecting said sensor response values into an evaluation space not dependent on the image-pickup light source through operations which can be colorimetrically approximated from spectral sensitivity characteristics of known image-pickup means and from spectral characteristics of an assumed test light source;

estimating the correct image-pickup light source by evaluating the correctness of a plurality of said test light sources based on a state of distribution of sampled values of the projected scene;

estimating the final image-pickup light source to be determined as the estimated light source by conjoining using numeric means, by selecting using conditional branching, or by both combined, the image-pickup light source determined by said estimation, and a light source determined by an estimation method different from said estimation; and

using, in color balance processing of the sensor response of said image-pickup means, spectral characteristics which are the color of the estimated image-pickup light source, or parameters appropriate thereto.